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Linking Snowmelt and Nitrogen Cycling to Vegetation Community Dynamics along a Hillslope Transect

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In recent years, rapid warming and early snowmelt have been observed with increasing frequency in the mountainous west. Although changes to water quantity are being increasingly analyzed, water quality with respect to nitrate is an important but often overlooked component in these environments. The objective of this work is to quantify the influence of variations in snowmelt timing and warming on nitrogen fluxes and plant phenology on a lower montane site in the East River catchment, Crested Butte, CO. In particular, we examine process couplings and mechanisms that guide nitrogen fluxes and plant behavior for an average hydrologic year (e.g., 2016), a deep snowpack (e.g., 2017) versus an unusually sparse and early melting snowpack year (e.g., 2018) as observed at the East River site. Additionally, we explore the impact of 1 degree incremental warming over the past 30 years. For this purpose, a hillslope-to-floodplain transect model has been developed using ecosys - a comprehensive plant ecosystem model that can account for surface energy exchange, microbial metabolism, vegetation phenology/physiology, as well as vertical and lateral hydrologic and biogeochemical fluxes.

Ecosys results demonstrate distinct spatial signatures of hydrological and biogeochemical fluxes along the hillslope transect, with greater evapotranspiration rates and higher soil water storage in the floodplain as compared to upslope regions. Further, shallow soil layers and deeper saprolite show prolonged saturation during high snow years, such that water availability in deeper saprolite extends through the monsoon season. In low snow years, evapotranspiration driven pre-summer drought occurs post-snowmelt. Consistent with observations, simulated results indicate that water deficit in surface soils in low snow years adversely impacts forb production and favors deep rooting shrubs altering vegetation nitrogen demand depending on topographic position. Simulation results therefore indicate that the timing of post-snowmelt precipitation is critical in sustaining plant productivity and dictating the length of the growing season. In comparison to baseline simulation, an earlier and larger NO_3 peak is obtained, with increased storage of N as ammonia with the warmer scenario. Overall, these findings demonstrate the significant spatial and temporal connection between climate change-associated nutrient storage/release and plant phenology along the hillslope.